the surface of the panel. The deformations induced lateral temperature gradients that increased the thermal stress within the panel. Finally, it was shown that panel bowing does not appreciably alter the trajectory-integrated heat load. The second figure shows computed surface and in-depth temperatures on a panel/support structure stack-up at the peak heating trajectory point.

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Aerothermal Analysis of the X-34 Vehicle

Grant Palmer, Susan Polsky

The X-34 vehicle will provide the first flight demonstration under NASA's Reusable Launch Vehicle (RLV) program of a fully reusable launch vehicle. Under a fixed-price contract with NASA, Orbital Sciences Corporation (OSC) is to provide a Mach 8 suborbital RLV technology demonstrator. The vehicle is 18.3 meters in length, has a wingspan of 8.4 meters, and is powered by a single LOX-kerosene engine. The X-34 is carried below an L-1011 aircraft to an altitude in excess of 9 kilometers, where the vehicles separate, the X-34 engine starts, and the X-34 vehicle continues along its flight trajectory. The first flight is scheduled for 1999.

Under a cooperative agreement with OSC, Ames Research Center was given the responsibility for designing, analyzing, and fabricating the thermal protection system (TPS) of the X-34 nosecap, wing leading edges, and rudder leading edge. Temperature, pressure, and heating rates on the surface of the X-34 were computed at six points along the X1004701 Mach 8.5 no-bounce trajectory. The work focused on the nosecap, wing/strake leading edges, and the rudder leading edge. These areas are protected from the thermal environments experienced during flight by silicone-impregnated reusable ceramic ablator tiles.

The computational data provided anchor points from which a time history of surface heating and pressure could be generated. This time history will be used to analyze and design the tiles. The figure shows computed surface-temperature contours at the peak heating point on the descent portion of the trajectory. The Navier–Stokes solutions were, when possible, compared with data from engineering correlations.

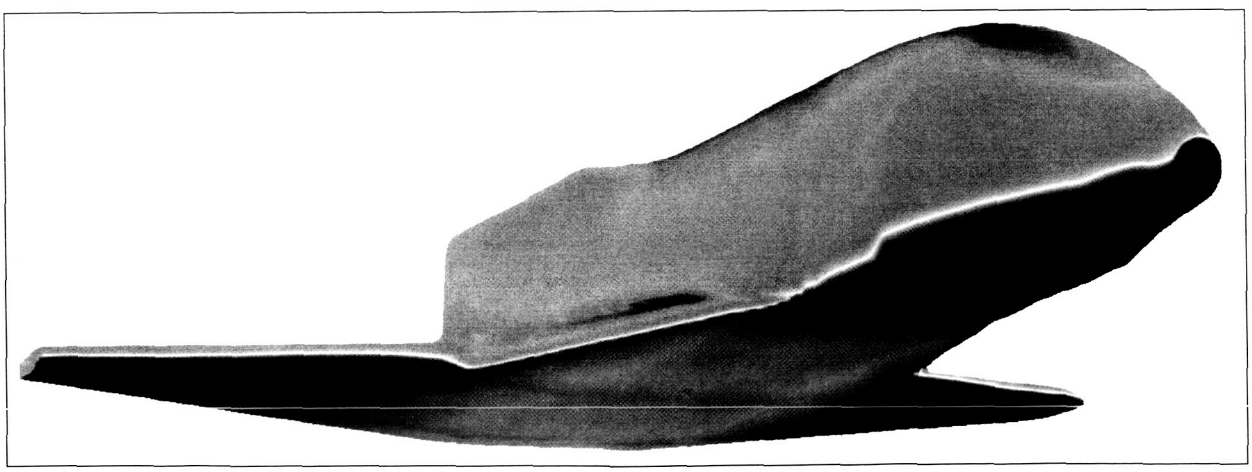

Fig. 1. Surface temperature contours.

The bow shock-wave impingement on the wing leading edge was also investigated. The location of impingement was a function of free-stream Mach number and vehicle angle of attack; no bow shock-wave impingement was seen on the rudder leading edge. A detailed grid sensitivity study was undertaken to establish an acceptable level of grid independence of the computed solutions.

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Sharp Leading Edges for Hypervelocity Vehicles

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Recent research shows that ultra-high temperature ceramics (UHTCs) may enable sharp leading edges to be used on space vehicles. Sharp leading edges (≤1 centimeter) could enable an entire new design space for hypervelocity vehicles with decreased drag, increased cross-range capability, and reduced cost-to-orbit. These factors, combined with results from ground-based testing and analysis, led to the implementation of the first UHTC flight demonstration. The objective of this flight was to validate the nonablating performance of a UHTC "sharp" leading edge by comparing flight data with theorized material performance data.

Implementation of the UHTC flight demonstration was a joint effort by Ames Research Center, Sandia National Laboratories, and the U.S. Air Force. A Minuteman III (MM III) launch/reentry opportunity was secured.

Ames designed a UHTC nosetip that sharpened the conventional Mk12A nose from a radius of 0.861 inch to 0.141 inch, as shown on the SHARP reentry vehicle, at the left in the figure. A microminiature thermocouple sensor was designed to measure the temperature within the nosetip. These articles were successfully fabricated, tested in the Ames arc-jet facility, and taken to Sandia National Laboratories for environmental testing. The reentry vehicle (RV) was flown to Vandenberg Air Force Base (VAFB) for further testing and integration with the MM III.

SHARP-B01 was launched from VAFB at 1:27 A.M., May 21, 1997. Once exoatmospheric, SHARP-B01 was deployed and entered Earth's

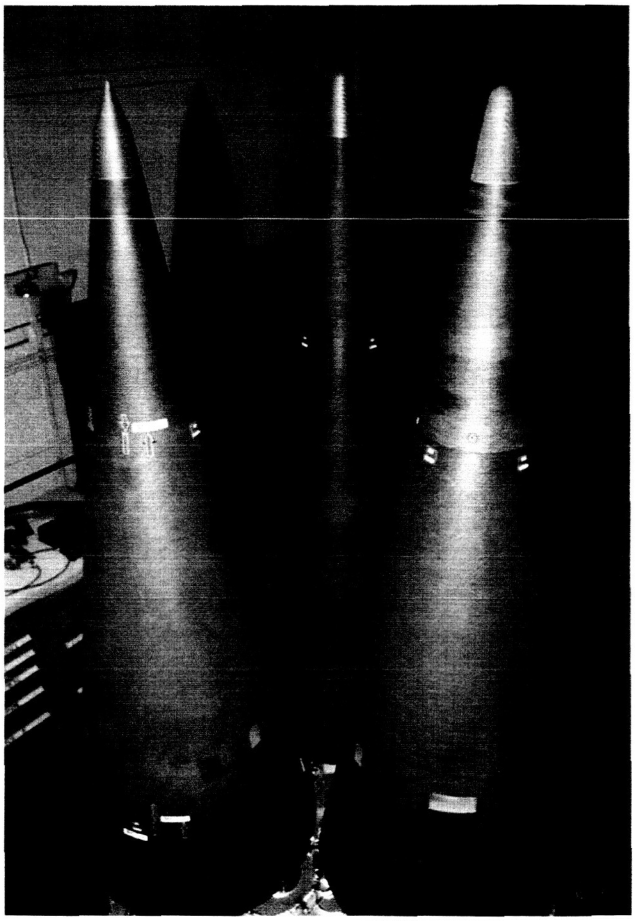

Fig. 1. The 0.141-inch radius nosetip SHARP-B01 reentry vehicle shown with standard Mk12A reentry vehicles.